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Combining Color Spaces for Human Skin Detection in Color Images using Skin Cluster Classifier

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***Abstract*- Skin detection remains a challenging task over several decades in spite of many techniques evolved. It is the elementary step of most of the computer vision applications like face recognition, human computer interaction, etc. It depends on the suitability of color space chosen, skin modeling and classification of skin and non-skin pixels under varying illumination conditions. This paper presents a symbolic interpretation on the performance of the color spaces using piecewise linear decision boundary classifier in color images to find the winning color space (s). The whole task is divided into three processes: analysis of color spaces individually; analysis of the combination of two color spaces; and finally making a comparative analysis among the results obtained by the above two processes. For performing the fair evaluation, the whole experiment is tested over commonly used databases. Based on the success rate, false positive and false negative of each color spaces, the winner(s) has been chosen among single and the combination of color spaces.**

***Index Terms*- Color space, Combination of two color spaces, Face detection, Piece-wise linear decision boundary method, Skin detection.**

I. Introduction

Skin detection is the process of detection of human skin region present in images or video using pixel-based or region-based information. Face recognition, steganography and several other applications of computer vision considered skin detection as a fundamental step [1]. It is the process of solving either one or two class classification problems. In one class classification problem, it tries to distinguish the object of an interest from the rest of other objects present in the input image, while in two class classification problem, it tries to discriminate the whole image into either skin or non-skin regions. Detection of human skin region comes under the latter category. In spite of many techniques evolved, the challenges faced by skin detection remains same over several decades. Requisite of color space chosen, skin modeling, and classification of pixels into skin or non-skin regions are the essential steps of it for the segmentation of the human skin region in color image(s). If the selection of color space and skin model has not chosen appropriately then the poor result will be returned by the skin detection techniques. The concept of color space has been basically used for searching human skin color cluster in their subspace as they are very useful in detecting and recognizing the human faces in color images. Different people belongs to different ethnicity have different skin races as well as the color images captured under different lighting conditions using different cameras arealso some challenges faced by skin detection at the timesegmentation process.

Different methods have been evolved to efficiently detect skin region in color images but they have their own shortcomings in the presence of varying illumination conditions. The commonly used skin detection techniques involve Gaussian model, Bayesian model, color-histogram approach, color-constancy approach [10], neural network [12], Genetic algorithm [11], etc using skin color information.

Variety of color spaces namely, YUV, YIQ, YCbCr, YCgCr, YES, RGB, and KL Transform, have been considered for testing the effectiveness of them to detect human face skin region with the skin pixel classification methods in the three past decades. Most of the researchers have used these color spaces with the piecewise linear decision boundary [2, 3, 4, 5] to detect human faces, tracking, recognition, etc. But the combination of two color spaces formed by making the possible combinations of these color spaces have not been researched till our knowledge. The main goal of the research is to get an effective threshold that helps to detect the human skin region under different races of human skin color, complex background as well as the different lighting conditions. The analysis of the color space individually and separately is one of the essential traces taken by the research to initiate the experiment. After that all the distinct possible combination of two color spaces are determined and every combination is considered to get the threshold for that combination using the images taking under the consideration of training set. Finally, the threshold values obtained as the experimental result are observed to decide which one has won the task for the detection of human skin regions among the single and combination of color spaces. The winning decision has been made by observing the number of missed and incorrectly identified color images. The presented work will be useful in the applications of the computer vision where these color spaces are used for skin detection.

The rest of the paper is organized as follows: section second focuses on the related work done previously. Third section gives the detailed idea of the presented work and the interpretation made on the results obtained by implementing the research work is discussed in fourth section. Finally, the conclusion about whole research work has been made in the last section.

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II. Related Work

Work done in the skin detection process has been rapidly and effectively increased in the previous years. As it is the preliminary step of most of the application so the yielded results should be more accurate in order to enhance the effectiveness of the applications like face recognition, human computer interaction, etc. As human skin color has its uniqueproperty from rest of the other features of human faces, it is commonly used to locate the human faces in still and video images by identifying skin and non-skin pixels [5].

Various researches have tried to make the skin detection automatic but still some challenges are still to be resolved. The accuracy of skin classification depends on the selection of color spaces as well as skin color model. Using the skin tone color information, Ibrahim et al. [1] has proposed a dynamic skin detector that would dynamically detect the adaptive thresholds using Viola Jones face detector algorithm. Selection of color space is based on the percentage of accuracy it will produce for particular task under given conditions. YES color space is used by Hsin-Chia et al. [8] for face detection and eye localization.

Nowadays, researchers are very much interested in the concept of fusion mixture of methods to enhance the detection rate of human skin region [9].

III.Skin Detection Method

Skin detection methods are commonly classified into two categories: pixel-based and region-based. In pixel based skin detection method, the pixel information of the images are used for the human skin classification, whereas in region-based, the concept of texture are used for the classification. Using the pixel information, skin detection methods are further classified into following sub-categories: explicitly defined skin region method, parametric method, non-parametric method, and semi-parametric method [6]. In explicitly defined skin region method, skin cluster is identified by finding the appropriate threshold that bound the human skin color during the training process using set of images for training. In parametric method, skin model requires much storage space and their performance directly depends on the representativeness of the training image set. This includes single and mixture Gaussian models. In non-parametric method, estimation is the key idea for skin color distribution from the set of images used for training without deriving an explicit model of the skin color. This method includes Bayesian model which performs fast computation and independent to the shape of skin distribution theoretically [7].

To deal with the performance of color spaces and their possible combination of two color spaces, explicitly defined skin region method is considered. It is the simplest method among all the other methods. It also produces good performance under different illumination conditions like different skin races, and different illumination conditions so this skin model is taken into account to perform the experimental computations

IV. Presented Work

The aim of the presented work is to find the color space that produces better result for the human face skin detection under different conditions among all the considered color spaces and all the possible combination of theirs for two color spaces. The whole task is classified into three categories which are further classified into sub-categories. The brief description of all categories is given as follows:

A. Skin Color Cluster Using Color Space Individually

RGB

RGB color space is the primary color space for still and video images. It is the simplest color space among all the evolved color spaces. This color space does not separate luminance and chrominance, and the R, G, and B components are highly correlated. The luminance of a given skin patch affects the component values of this color space as it is computed by using the linear combination of the R, G, and B values. As the illumination conditions change, the location of the human skin cluster available in their subspace will change. Instead of facing these challenges, RGB is extensively used in the skin detection. The inequalities for clustering the human skin color are given as follows:

$$R > 95, G > 40, B > 20, (max - min) < 15,$$
$$R > G, R > B, (R - G) > 15 \quad (1)$$

YUV

It also belongs to the family of orthogonal color spaces used in video media. The property of this color space is very much similar to the YUV color space. I and Q are chrominance components for this color space. These components are used for finding skin cluster in given images as they will not get affect from changing the illumination conditions. The experimentally obtained thresholds are given as follows:

$$75 < U < 200, 30 < V < 110 \quad (2)$$

YIQ

It also belongs to the family of orthogonal color spaces used in video media. The property of this color space is very much similar to the YUV color space. I and Q are chrominance components for this color space. These components are used for finding skin cluster in given images as they will not get affect from changing the illumination conditions. The experimentally obtained thresholds are given as follows:

$$110 < I < 170, 75 < Q < 200 \quad (3)$$

YCbCr

YCbCr is a family of color space used as a part of the color image pipeline in video and digital photography systems. It is obtained by the linear combination of RGB components. The thresholds obtained for clustering human skin tone color using chrominance components, Cb and Cr under different illumination conditions are given as follows:

$$85 < Cb < 135, 135 < Cr < 180, Y > 80 \quad (4)$$

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YCgCr

This color space is based on the colorimetric applications to television systems. It has used G-Y instead of B-Y which is used for analysis applications of face segmentation. It is derived from the components of YCbCr color space [4]. In order to precisely classify the skin and non-skin regions, the threshold values should be properly determined by using training set during experiment. The thresholds determined during training process are given as follows:

$$75 < Cg < 250, 10 < Cr < 100 \quad (5)$$

YES

This color space is linearly derived from the RGB components. E and S are the chrominance components that help to precisely discriminate the human skin and non-skin pixels. The thresholds that are explicitly applied for this purpose are experimentally computed and are given as follows:

$$Y > 80, E > 167 \quad (6)$$

KL Transform.

From the point of geometrical interpretation, it translates and rotates the axes and establishes a new coordinate according to the variance of the data [13]. The possible threshold obtained after the training process are as follows:

$$0 < KL1 < 210, 5 < KL2 < 115 \quad (7)$$

B. Skin color cluster using combination of two color spaces

The concept of combination of two color spaces has been used to make the skin methods more effective. This concept has used by some of the researchers for limited number of color space [5, 13, 14]. But all possible combination of two color spaces is considered which are not yet to be researched to the best of our knowledge. In the combination of two color spaces, the chrominance components of both the color spaces are taken into an account so that the intensity will not get affect by changing the illumination conditions. Using AND operator, the chrominance components are combined and a proper threshold values are applied which is trained during the training process using set of color images to detect the skin and non-skin pixels precisely and efficiently.

V. Experimental Results And Discussions

The whole experiment is concised around the classification of skin and non-skin pixels by applying the explicitly defined threshold values obtained by extensive iteration under the training process. The results obtained produce better results not only under the presence of different skin races as well as different lighting conditions too. For the detection of human face skin region, the accuracy of each single and combination of color spaces are compared by examining the errors obtained at the moment of skin classification. Under the skin classification, two types of errors commonly occur. They are false positive and false negative. False positive represents the wrong labeling of a non-skin pixel as skin pixel. False negative represents the wrong labeling of skin as non-skin pixels. A skin classifier is considered as good only when it has low false positive and false negative rates.

The experiment is started with the analysis of color spaces individually and independently. The success rate of each color spaces are shown in table 1. Firstly, RGB color space is taken into an account as it is the commonly used in images because of its simplicity. The results showed that it effectively distinguishes the skin and non-pixels in static images having different races of human skin tone color. But as the lightning conditions vary it includes some non-skin pixels as skin pixels. This color space precisely specifies the human facial features.

YUV color space has produced the better result in static images as compared to RGB color space having different skin races but with the varying lighting conditions it doesn't produce very adequate result.

Like YUV, YIQ color space has yielded same result with 96% the success rate. The challenges that it faced is in the clear discrimination of complex background from the interested objects present in images.

Table I. Skin Detection Rates Of Color Spaces Individually

Name of the color space	Percentage of success rate	False positiv e rate	False negati ve rate
RGB	93	0.05	0.00
YUV	96	0.05	0.00
YIQ	96	0.09	0.05
YCbCr	96	0.05	0.00
YCgCr	91	0.00	0.09
YES	96	0.05	0.02
KL Transform	89	0.05	0.07

YCbCr color space is the commonly used color space for skin detection. It has yielded good result in terms of skin segmentation, facial feature identification background classification under different races. It has also given adequate result under the varying lighting conditions among the above discussed color spaces.

YCgCr color space has clearly discriminated the object of an interest from the complex background under different human skin races as well as lighting conditions. The challenges it has faced that it doesn't make a clear separation line to the skin segmented and non-skin segmented region.

YES color space has precisely distinguished between skin and non-skin pixels in image. This color space is less affected by changing the illumination conditions. The skin classifier error rate can be acceptable.

Lastly, KL transform color space has experimented in which the rate of false negative has more occurred as compared to false positive. Some of the results produced by using the above discussed color spaces with the skin cluster technique have properly shown in fig. 1.The figure show the clear analysis on the effects of lighting and different races ofhuman skin tone color during the segmentation of skin region. Now, the second analysis has been made on the

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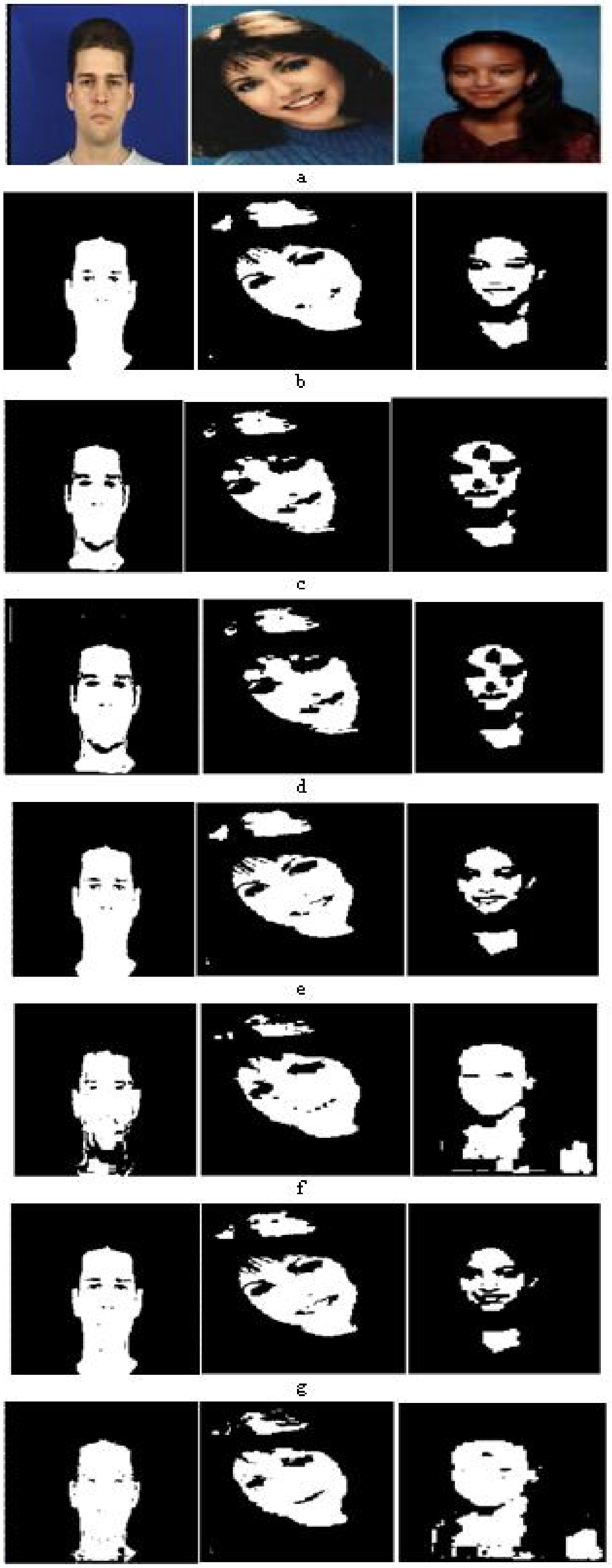

Figure 1. Sample Outputs. a. Input images, b. RGB, c. YUV, d. YIQ, e. YCbCr, f. YCgCr, g. YES and h. KLtransform color space

combination of two color spaces using the skin cluster approach. Characterization of each combination has been made on the basis of results yielded by them during experimental evaluation using same database.

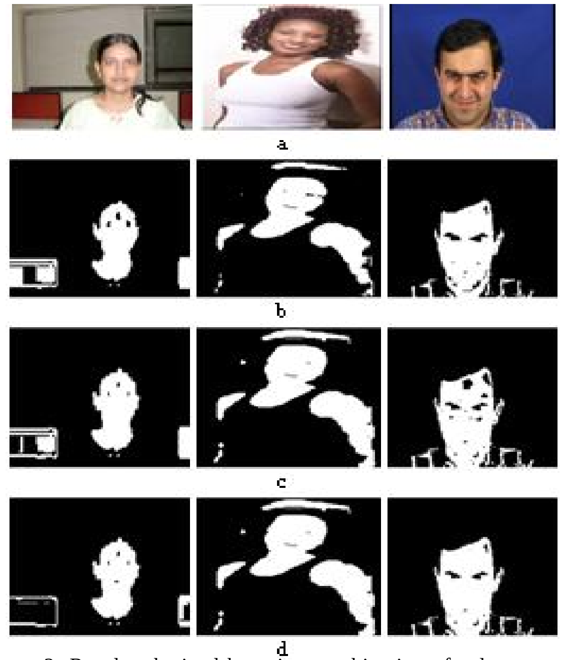

Figure 2. Results obtained by using combination of color spaces a. Sample images, b. YCbCr-YCgCr, c. YCbCr-YES and d. YCbCr-KL transform color space

TABLE II. SKIN DETECTION RATES OF COMBINATION OF TWO COLOR SPACES

Name of the color space	Percentage of success rate	False positive rate	False negative rate
RGB-YUV	91	0.02	0.1
RGB-YIQ	75	0.2	0.11
RGB-YCbCr	96	0.02	0.05
RGB-YCgCr	91	0.02	0.1
RGB-YES	91	0.02	0.1
RGB-KL	73	0.18	0.09
YUV-YIQ	96	0.05	0.00
YUV-YCbCr	93	0.05	0.05
YUV-YCgCr	96	0.05	0.02
YUV-YES	89	0.05	0.11
YUV-KL	96	0.05	0.00
YIQ-YCbCr	91	0.07	0.05
YIQ-YCgCr	96	0.05	0.02
YIQ-YES	91	0.05	0.1
YIQ-KL	75	0.2	0.07
YCbCr-YCgCr	91	0.05	0.05
YCbCr-YES	89	0.05	0.1
YCbCr-KL	91	0.05	0.05
YCgCr-YES	96	0.05	0.00
YCgCr-KL	96	0.05	0.00
YES-KL	77	0.05	0.16

The purpose of making combinations is to analyze which one either single or combinations of two color spaces produce better result for skin detection. One of the observation made using each combinations is that combination doesn't always produces better result as compared to single color spaces. The concept is basically used to suppress some of the pitfalls of one color space with the merits of other color space. It may or may not be happen that the yielded result

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have badly detected skin region. The detailed explanation of the analysis of combinations of two color spaces is started with the combinations YCbCr-YCgCr, YCbCr-YES and YCbCr-KL transform color spaces. All the three combinations have shown good results as shown in fig. 2 with the varying skin tone color of human faces as well as with the alternate lighting conditions. They have clearly classified human skin and non-skin regions. The only challenge they had faced is the presence of objects which are red in color.

The specification of each combination is started with the combinations having RGB as common color space namely, RGB-YUV, RGB-YIQ, RGB-YCbCr, RGB-YCgCr, RGB-YES, and RGB-KL transform. RGB has the advantage of precisely detection in facial feature of human faces as shown in figure 1. On combining it with the other color spaces, it has yielded the results shown in figure 3 and the success rate with the skin classifier error rate of all possible combinations of two color spaces are shown in table 2.

Figure 3. Results obtained by using RGB-YUV, RGB-YIQ, RGB-YCbCr, RGB-YCgCr, RGB-YES and RGB-KL transform color space respectively

RGB-KL and RGB-YIQ have clearly shown the background classification problem. RGB-KL has not produced good result with the varying illumination conditions also. Thecombination of RGB-YCbCr and RGB-YCgCr has yielded same result as YCgCr has evolved from YCbCr so it has some similar properties of YCbCr.

Figure 4 has shown the results yielded by the distinct combinations formed by using YUV as a common color space. All of them have yielded good result with the alternate skin tone and lighting conditions.

Figure 5 and 6 has showed the results of the remaining combinations. YUV-YIQ is the combination that has produced better result in static images with varying skin tone color but static illumination conditions

Figure 4. Results obtained by using YUV-YIQ, YUV-YCbCr, YUV-YCgCr, YUV-YES and YUV-KL transform color space respectively

The combinations having the YCbCr, YCgCr as one of the color space have yielded better result with the varying lighting conditions. KL transform has not affected much with the fluctuation of skin tone color and lighting conditions.

There are three combinations that win the task out of 21 possible combinations of two color spaces namely, YUV-YIQ, YUV-KL, and YCgCr-YES

VI. Conclusion

The color spaces with distinct possible combination of two color spaces formed by them are considered using pixel-based skin classification algorithm. Analysis of single color spaces has yielded good result only in static conditions. They have not yielded good result under varying lighting conditions. Unlike single color space, the combinations of two color spaces have produced good results with the alternate human face skin tone color as well as lighting conditions. The combinations that have produced 96% highest success rate with lesser false positive and false negative are YUV-YIQ, YUV-KL transform, and YCgCr-YES color spaces

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Figure 5. Results obtained by using YCgCr-YES, YCgCr-KL and YES-KL color space respectively

Figure 6. Results obtained by using YIQ-YCbCr, YIQ-YCgCr, YIQ-YES and YIQ-KLtransform color space respectively

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